Ultrafast Transient Recording Enhancements for Optical-Streak Cameras

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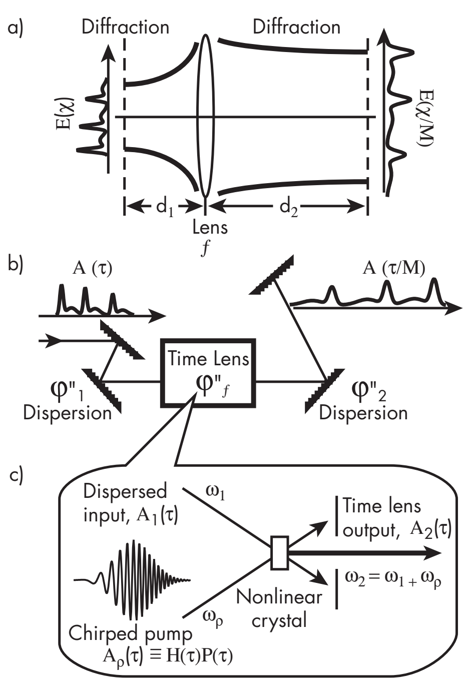
Several experiments at LLNL will require hard x-ray and neutron diagnostics with temporal resolution of approximately 1 ps (or less) and a high dynamic range, particularly those experiments involving ignition. The Linac Coherent Light Source (LCLS) at the Stanford Linear Accelerator Center (SLAC) will need to measure timing and pulse shapes of its 100-fs fwhm x-ray pulse. These measurement requirements are far beyond existing solutions.

This project will develop a "time-microscope" front end for optical streak cameras. It will magnify signals having ultrafast optical detail so that they can be recorded with slower speed streak cameras with a much higher fidelity. The system will be compatible with a new class of ultrafast radiation detectors being developed, which produce a modulated optical carrier in response to ionizing radiation.

Figure 1. Comparison of (a) spatial and (b) temporal imaging systems. A time lens (c) is produced by mixing the input signal with a chirped optical pump pulse.



Project Goals

Temporal imaging is based on a space-time duality between how a beam of light spreads due to diffraction as it propagates in space, and how pulses of light spread as they propagate through dispersive media, such as grating systems or optical fiber (Fig. 1.) We have chosen to implement a "time lens" through sum-frequency generation (SFG) of a broadband-chirped optical pump with the input signal in a nonlinear crystal because of the improved resolution it produces.

This project will develop a temporal imaging system using fiber optic technologies. It will accept an optical signal at a 1550-nm wavelength that has around 600-ps duration and subpicosecond detail. The system will have a temporal resolution < 300 fs and will produce an output with 100 × temporal magnification, simultaneously shifting the signal to a 775-nm-center wavelength. The 300-fs input details, magnified to 30 ps at the output, will then be recorded with high fidelity on an optical streak camera.

Relevance to LLNL Mission

The success of NIF is critical to LLNL's stockpile stewardship mission. Our goal is to ensure delivery of the next-generation ultrafast diagnostics needed for critical experiments at NIF and other facilities, such as LCLS.

FY2004 Accomplishments and Results

We have performed an initial design of our temporal imaging system and modeled it in LinkSim (Fig. 2), with co-simulation in MATLAB. The model starts with a "RadSensor" generating an input pattern and a mode-locked laser, which is used to generate the chirped time lens pump pulse. Signals propagate through modulators, fibers, and amplifier modules containing the approximate characteristics of the intended components. They combine in a module that exports the data to MATLAB to simulate SFG in a nonlinear crystal. The simulation returns to LinkSim, propagates through the output dispersion module, and plots the output waveform. The input and output are plotted on 5 ps/div and 0.5 ns/div scales, respectively, a 100 × magnification. The output is blurred slightly and has ripple to one side due to non-idealities in the input dispersion. This preliminary model will be revised as the design is improved and actual components are measured.

Precision dispersion measurement for each component is critical to understanding the cause of aberrations like that shown in Fig. 2. We have constructed such a measurement system and are currently using it to characterize all our components. With this information steps can be taken to remove the aberrations.

Construction of the temporal imaging system has begun with the time lens. Figure 3 shows the laser system and pulse picker.

Related References

1. Bennett, C. V., and B. H. Kolner, "Upconversion Time Microscope Demonstrating 103x Magnification of Femtosecond Waveforms," *Optics Letters,* **24,** (11), pp. 783-785, June 1, 1999.
2. Bennett, C. V., and B. H. Kolner, "Principles of Parametric Temporal Imaging-Part I: System Configurations," *IEEE J. Quantum Electronics,* **36,** (4), pp. 430-437, April 2000.
3. Bennett, C. V., and B. H. Kolner, "Principles of Parametric Temporal Imaging-Part II: System Performance," *IEEE J. Quantum Electronics,* **36,** (6), pp. 649-655, June 2000.
4. Bennett, C. V., and B. H. Kolner, "Aberrations in Temporal Imaging," *IEEE J. Quantum Electronics,* **37,** (1), pp. 20-32, January 2001.

FY2005 Proposed Work

We will proceed with completion of the time lens system. We will generate the required chirped pump pulse and design and implement the nonlinear crystal that will impart those characteristics through SFG with the input. An improved input dispersion design will be developed and implemented to remove the aberrations predicted in Fig. 2. We will also develop timing and triggering systems compatible with NIF.

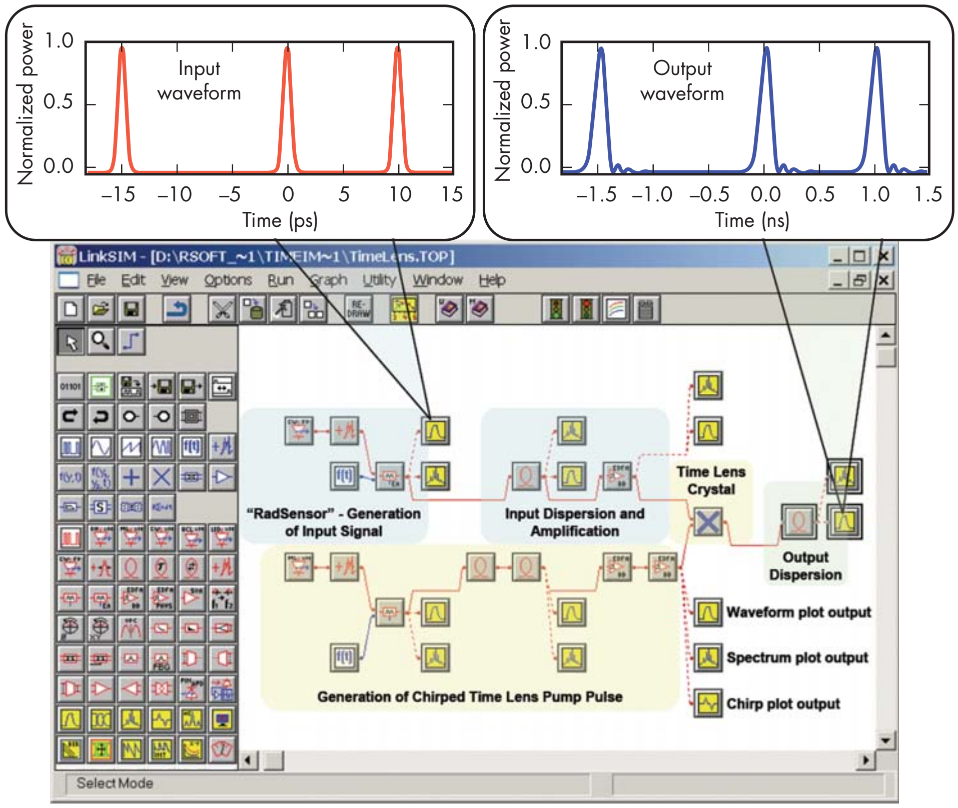


Figure 2. Layout of our initial system design in LinkSim along with input and output waveforms.

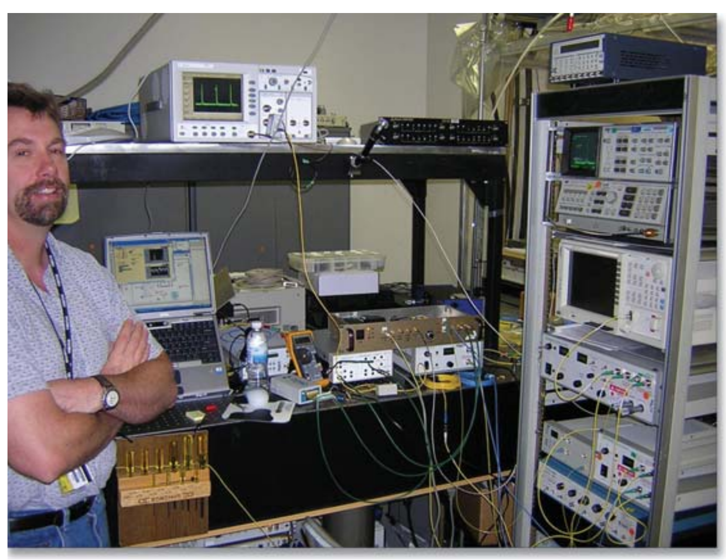


Figure 3. Bryan Moran optimizing the mode-locked fiber laser and pulse picking system. These are the initial components in the chain that generates the chirped time lens pump pulse.